

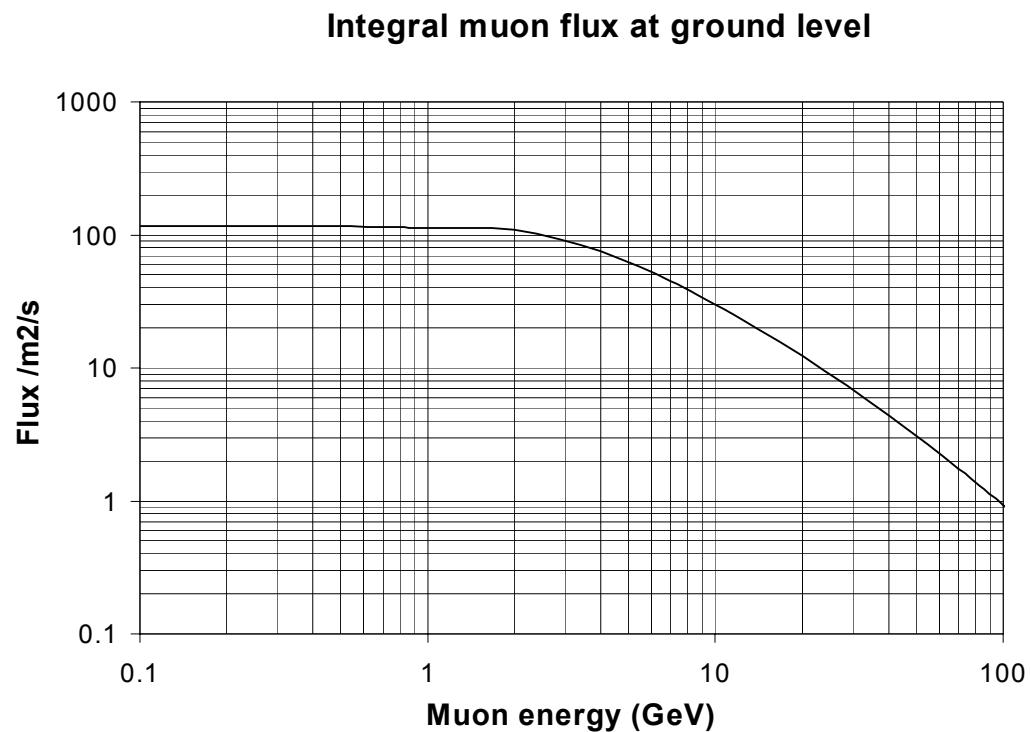
Cosmic Ray Induced Backgrounds

Keith Ruddick, University of Minnesota

- Ground-level fluxes – remnants of extensive air showers
(atmosphere is calorimeter with $\sim 10 \bullet_{\text{int}}$ and $\sim 25 X_0$)
- Rates in detector
(will assume $20 \times 20 \times 50 \text{m} \times 1000 \text{ m}^2$ effective area)
- Effect of overburden
- Interactions with non-detected muon

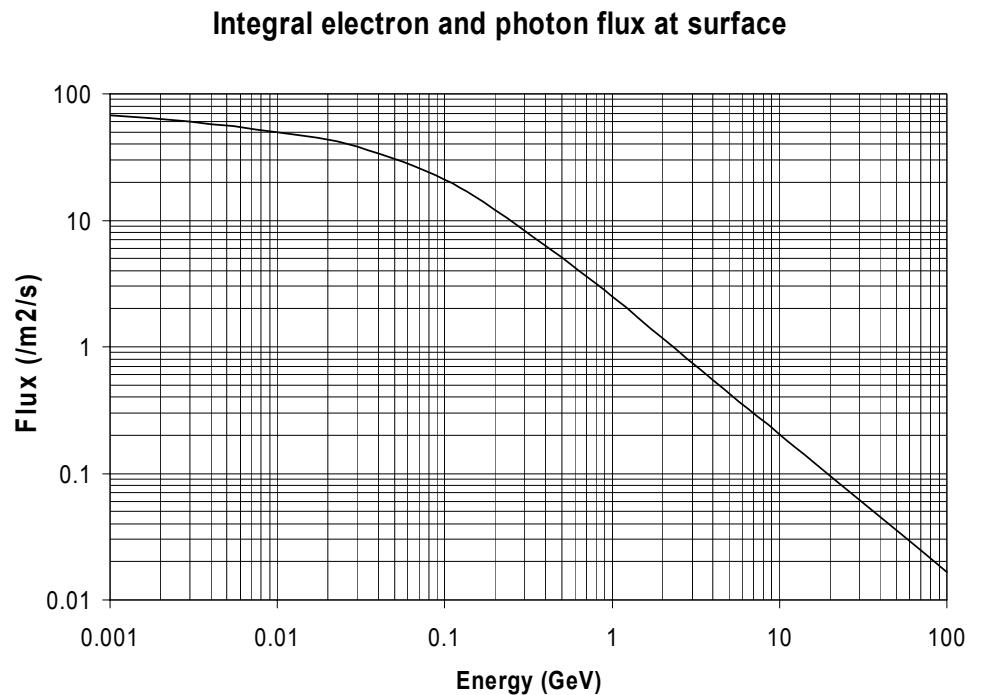
Muons

- Ang. Dist. "cos²□"
- Most prob. angle "35°"
- Median energy "4 GeV"
- " 50% stop in 20 m detector ($\square = 1 \text{ g/cm}^3$)



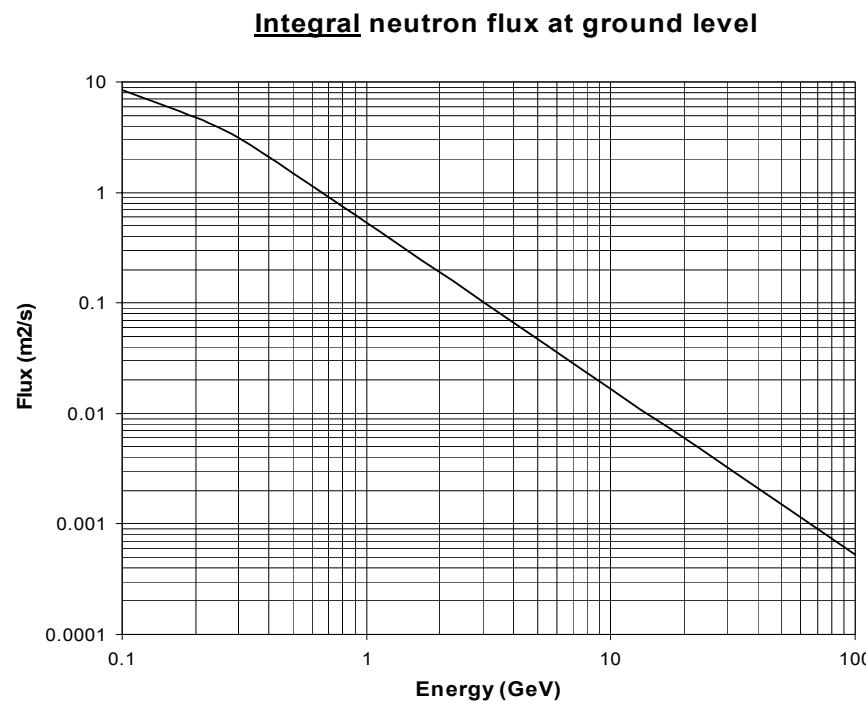
Electrons and photons

- Data from Daniels and Stephens; Revs Geophys. And Space Sci. 12, 233(1974)
- "cos²□ for □ < 60°
- Median energy " 10s of MeV
- Attenuated as "exp(-x/175g.cm⁻²)

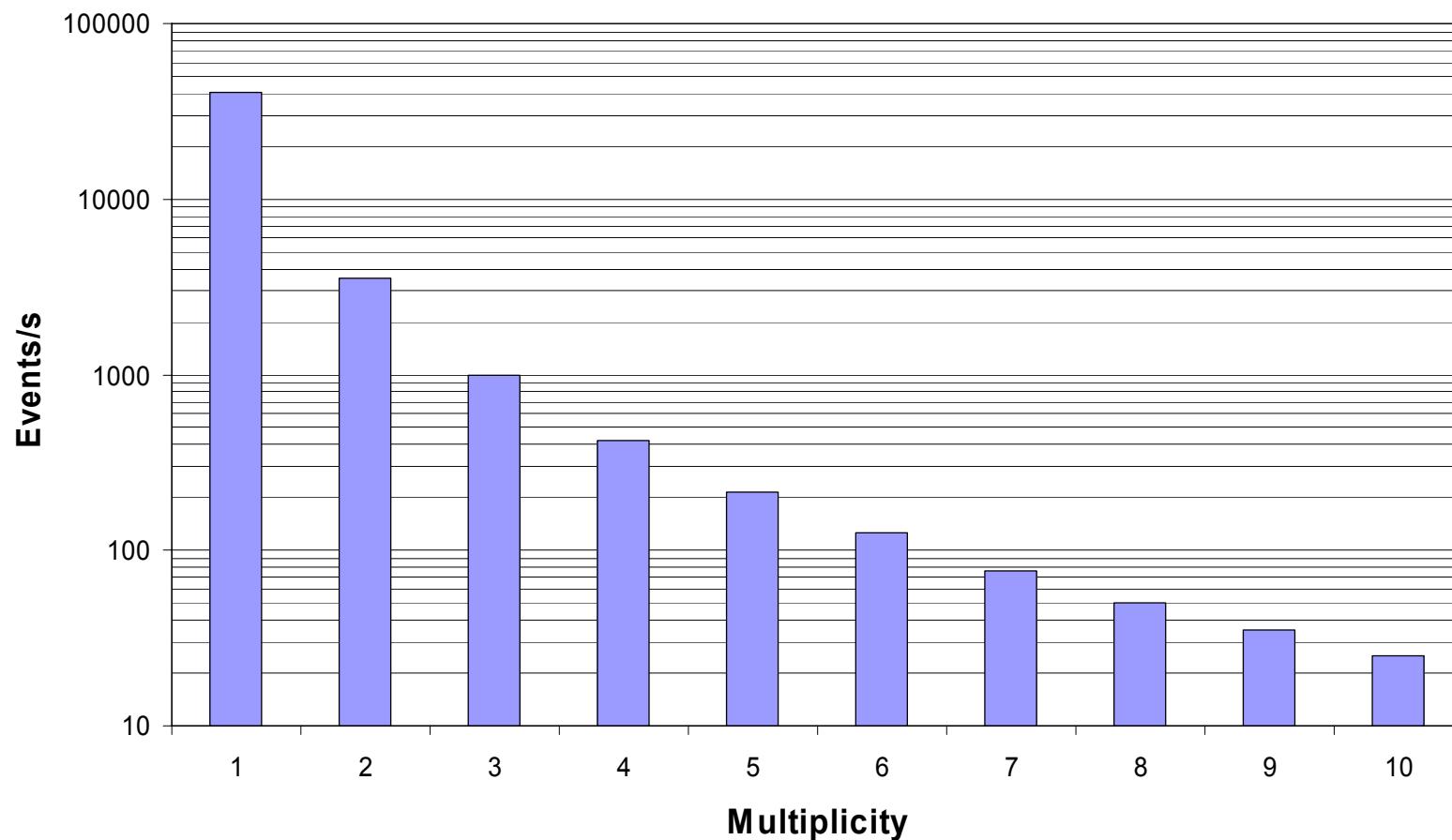


Neutrons

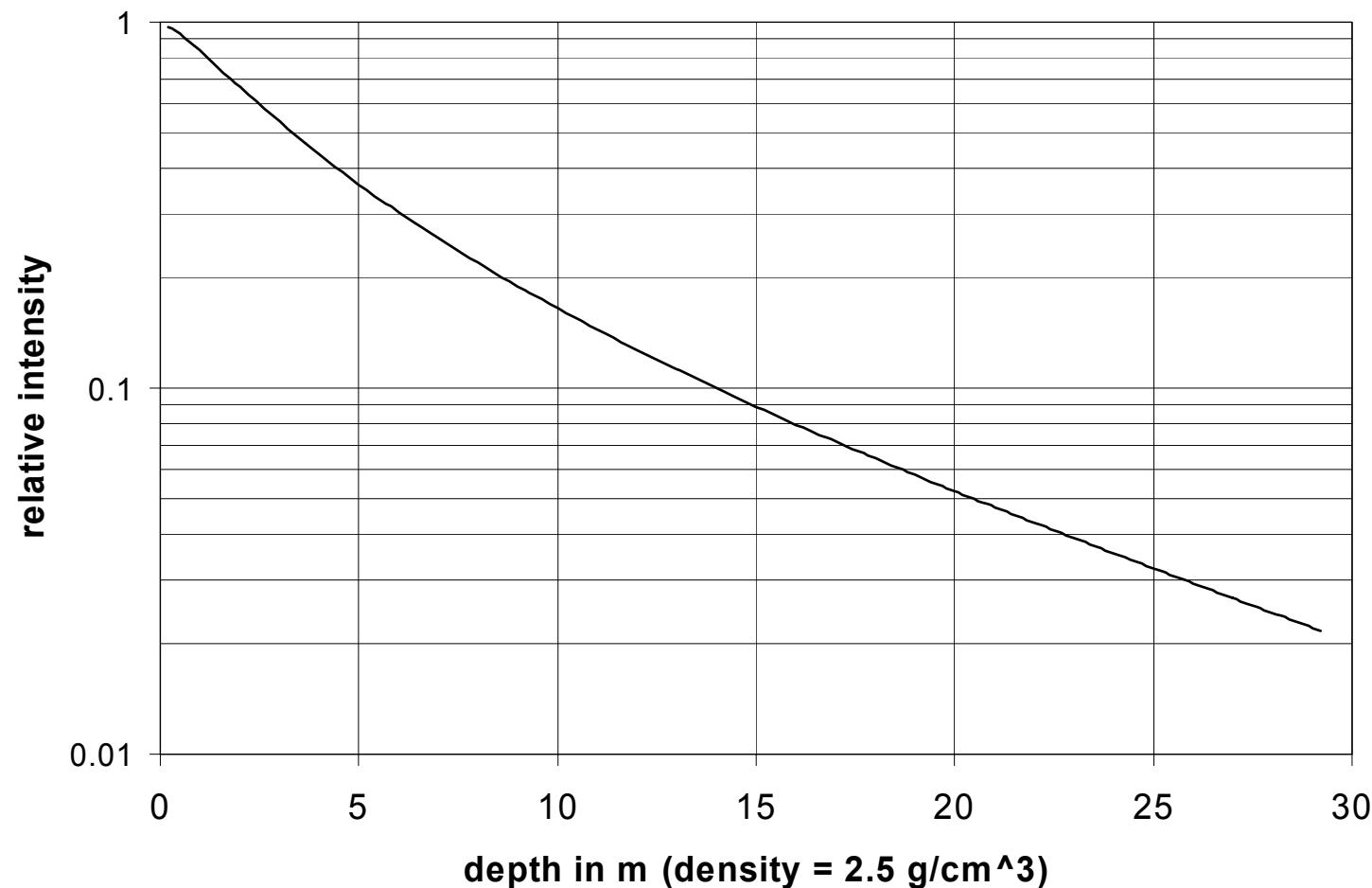
- Data from Ashton, “*CR at ground level*”, ed. Wolfendale (1974)
- Atten. Length ”120 g/cm²
- $I(\square) \odot I(0)\exp(-8(\sec \square - 1))$



Muon multiplicity in 1000 sq.m. detector



Muon flux vs overburden



Rates in 1000 m² detector

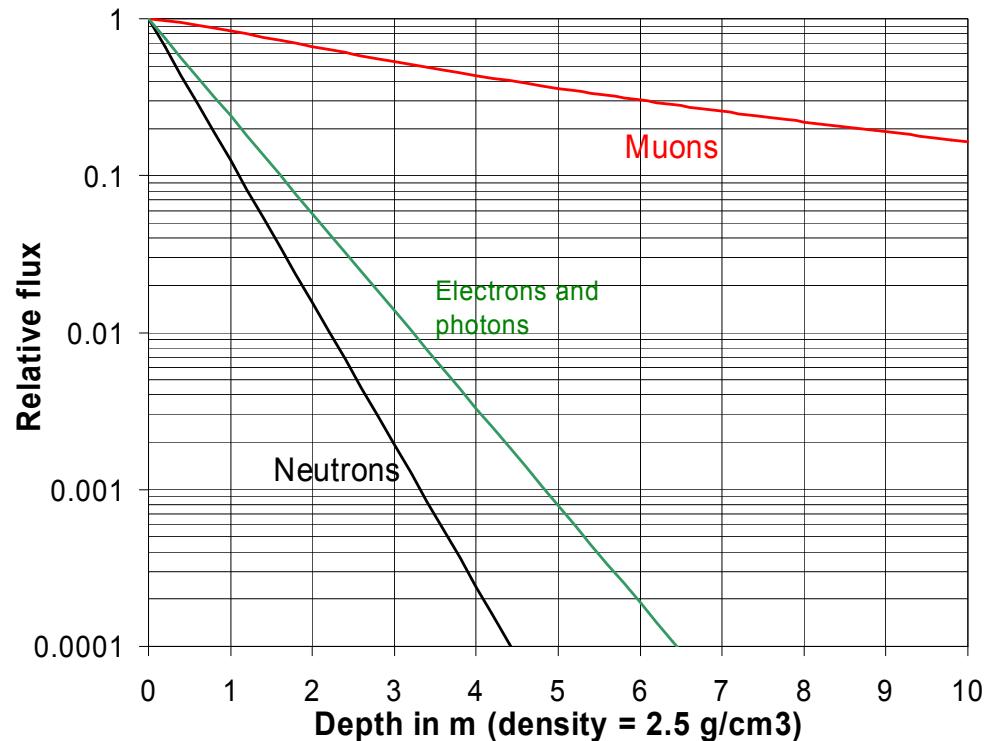
- no overburden

- Muons/10Os spill = 1.2
- Muons/year = $1.2 \diamond 10^7$
(10^7 spill/yr \diamond 100 s live-time/yr)
- Electrons/photons ” 1/2 of this
- Neutrons/year = $8 \diamond 10^5$ ($> .1$ GeV)
= $5 \diamond 10^4$ (> 1 GeV)

Effect of overburden

Assume density = 2.5 g/cm²

- Muons:
3m cuts by factor "2
5m cuts by factor "3
- Neutrons:
3m cuts by factor "500
($\uparrow 100/\text{yr} > 1\text{GeV}$)
5m cuts by factor " $3 \diamond 10^4$
($2/\text{yr} > 1\text{GeV}$)
- N.B. neutrons also produced in overburden by muon hadronic interactions (e.g. see F.Boehm et al., PR D62,092005-1,2001)

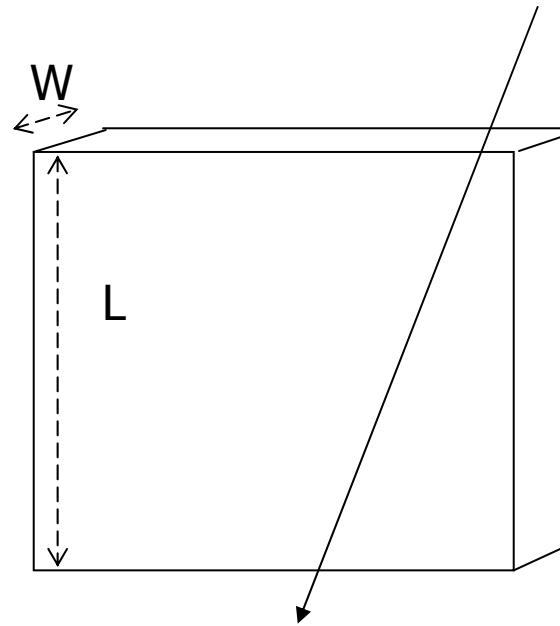


Neutron production by muons

- From extrapolation of Boehm et al.
Rate is 2.5×10^{-5} n/g.cm⁻²/muon at 10 mwe (4 m)
 \bullet 0.025 neutron/mu in 1 \bullet_{int}
- These are produced in large cascades with many accompanying hadrons
- Assuming same energy spectrum as EAS remnants (??)
"1% have energy > 1 GeV (this number is iffy-needs more study)
- **” 3000 neutrons (>1GeV)/year produced in overburden**
- **These are accompanied by muon and other products of hadronic cascade**
- **” 3 to 5 m overburden is optimal ? – rate produced in overburden” rate attenuated by overburden**
- **N.B. \bullet_{int} 100g/cm² 1 m fiducial volume cut**

Principal source of background events?

1. \odot passes through absorber undetected.



$$\text{⌚⌚} \odot WL/L^2 = W/L$$

$$\Phi_{\text{total}} = 2\pi/3 (I'' \cos^2\theta)$$

⌚ fraction of unseen \odot \odot W/2L
(about 0.4%)

2. \odot produces a \square^0 which is seen in detector:

-see J. Delorme et al., PR C52, 2222 (1995)

$$E_\odot = 0 - 0.5 \text{ GeV: } 0.78 \diamond 10^{-6} \text{ /g.cm}^{-2}/\odot \text{ at 20 mwe depth}$$

$$E_\odot = 0.5 - 10 \text{ GeV: } 1.96 \diamond 10^{-6} \text{ /g.cm}^{-2}/\odot$$

$$E_\odot = 10 - 100 \text{ GeV: } 0.22 \diamond 10^{-6} \text{ /g.cm}^{-2}/\odot$$

3. Total $\odot 2 \diamond 10^{-6} \square L \diamond W/2L \odot 10^{-6} \square W/\text{muon} \odot 1.5 \diamond 10^{-5} \text{ events/muon}$

⌚ “ 200 events/year (20kT detector)

Are such events really a problem?

Discriminating factors:

- Directionality - events are orthogonal to beam direction
- They are generally part of a hadronic shower – will generally detect associated particles
 - Worst case scenario: e.g., \square^o emitted isotropically – with only 10^o ang res'n, a fraction $\odot 10^{-2}$ point in beam direction
- Energy – requires simulations to determine disrim factor.?
- \square^o/e discrimination: better be excellent!
- Negligible source of background

⑥ 1/year

Is an active shield necessary?

- For 20 \diamond 20 \diamond 50 m detector with 250 active detector planes, need to cover area "3000m²
- This is "3% of detector active area
- Singles rates in RPC or scintillator
"100Hz/m² muons + "100Hz/m² external γ -radiation
 - 1 MHz total + detector noise
- Calculations suggest that shield not needed, but extra security probably worth it
- Good investment and also politically expedient?